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ICUD-0501 From vision to operation - Smart real-time control of water systems in Aarhus, Denmark

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Summary

The city of Aarhus, Denmark, is currently implementing a solution for “Smart Real-Rime Control of Water Systems”. The project focuses on improving the operation of urban drainage systems by using a new modelling approach that combines traditional physically-based models with fast surrogate models and a model predictive control (MPC) framework for real-time system optimization. This abstract presents the principles of the new modeling approach as well as the overall status and results of the Aarhus implementation.

Keywords

integrated urban water management, model predictive control, real-time control, smart cities, urban drainage, MPC

Introduction

A significant number of cities across the globe are facing major water system challenges related to urbanization and climate change. One central element shared by most cities is the challenges related to how to capitalize on an increasing volume of data to improve operations. It can be argued that the water sector is generally data rich yet information poor.

The key to smart real-time control of water systems is to facilitate the process outlined in Fig. 1 where the path from a descriptive system (pure data) to a prescriptive system (data, models and system optimization) is illustrated. A descriptive system is defined as a system where output is limited to referring the data using textual and graphical visualizations. This often evolves into a more diagnostic-focused system where data are analyzed and perhaps modelled to establish a wider information base to act upon. A diagnostic system can be running in real-time but in order to support decision makers forecasting capabilities often are desired and incorporated. Thereby the diagnostic system progresses into a predictive system. The last step on the evolution is a true prescriptive system where real-time control is implemented and optimized using predictive models.

The drivers for Smart Real-Time Control of Water Systems are first and foremost financial since the approach can reduce the needs and related costs of enlarging and upgrading existing urban water infrastructure required to meet increasing urbanization and climate adaption. It also supports the desire for reducing the costs associated with storm water management by supporting mitigation measures and optimizing existing storage capacity (Frier et al., 2013).

Methods and Materials

To advance the concept of integrated real-time control of water systems, an innovative technology framework has been developed as part of a collaborative research effort. The framework facilitates progression from data (descriptive system) to smart real-time control of water systems (prescriptive) in a proven, cost-effective manner as an alternative to the conventional approach of increasing physical system capacity.

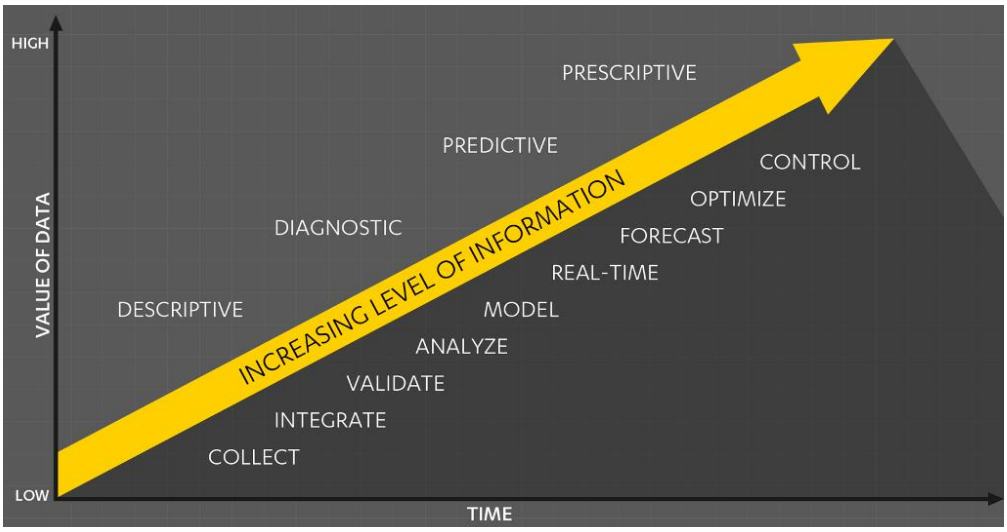

Fig. 1. *Transformation path for advancing from data to operational decisions*

The core of the framework is a generalized data management platform, which can be used within all water domains. This platform integrates time series data and spatial data with numerical models, and offers a broad suite of tools for data processing and reporting. Data processing tools can be executed as automated workflows that replace tedious and error prone manual tasks.

A key element of the project is the development of fast and accurate surrogate models of complex physical systems, complementing standard physically-based models adapted to observations in real time in order to ensure efficiency and performance of the automated MPC algorithms.

A second element is the utilization of weather radar data. Distributed rainfall observations and forecasts are essential for optimizing the use of the system capacity but they are uncertain, and the MPC method employed therefore considers uncertainty of the forecasts to provide robust solutions.

Results and Discussion

An essential part of the project is the application of the MPC framework in an operational context. Aarhus Water Utility in Denmark is partner in the project and they deliver crucial design input as well as valuable operational experience in automated integrated operational control of urban water systems. Being one of the very frontrunners on the application of this type of systems they have extensive experiences in operating an automated control system based on data and deterministic models coupled with an optimization scheme. The whole system is mirrored into a “sandbox” allowing for full scale testing and evaluation of new control methods without interfering with the operational part of the system. This unique setup is utilized in the project where the MPC framework is being tested and evaluated based on a significant part of the Aarhus Water System in the sandbox, cf. Fig. 2. The testing and evaluation is done in close cooperation with the operational staff at Aarhus Water to ensure the developed MPC framework solution is applicable in a real-time operational organization.

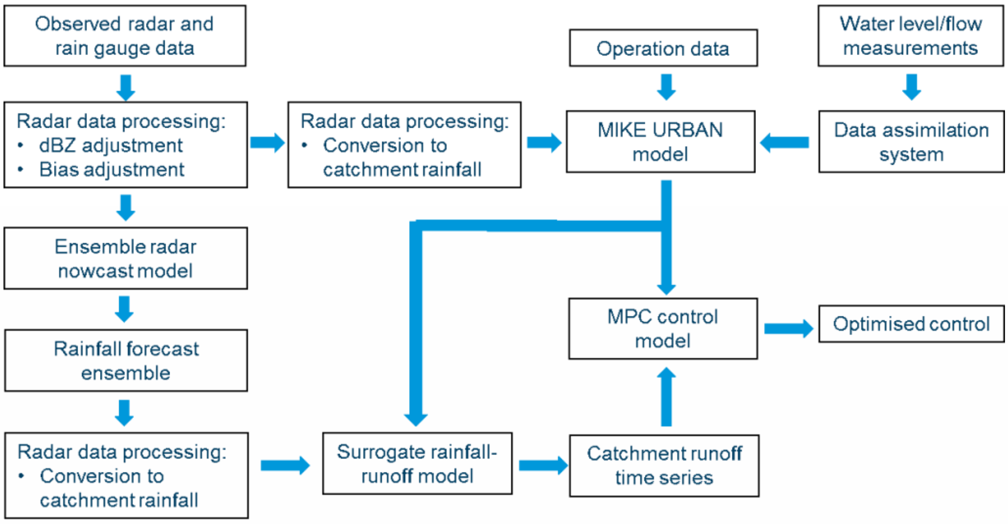

***Fig. 2**. Established workflow for the real-time control system*

The initial results of the testing indicates significant potentials for meeting the objectives of prioritize and minimize combined sewer overflows in individual locations. In the first test phase a 24.6% total overflow volume reduction compared to the existing control strategy was realized. Detailed results and graphical representation of the results is reported in Halvgaard et. al, 2017. It should be noted that the MPC model is subject to some limitations such as backwater effects is not modelled, the test is based on perfect inflow forecasts based on the historic runoffs and the MPC performance depends highly on the underlying control layer design

Conclusions

The developed generalized technology framework supports the application of the MPC methodology in a flexible and usable manner. The framework supports a one-stop approach for handling the full workflow from data acquisition to MPC execution and evaluation with hydrodynamic models - and distribution of control set points to the existing SCADA and high-level information dissemination to the operators and other stakeholders.

Acknowledgement

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